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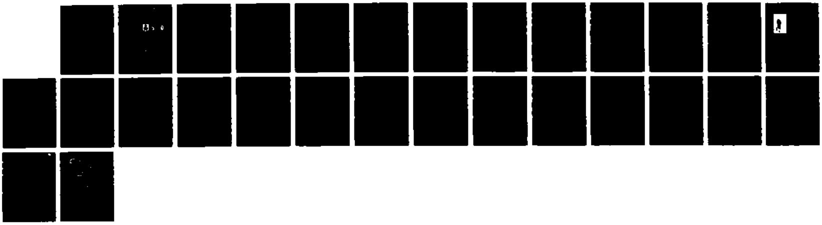

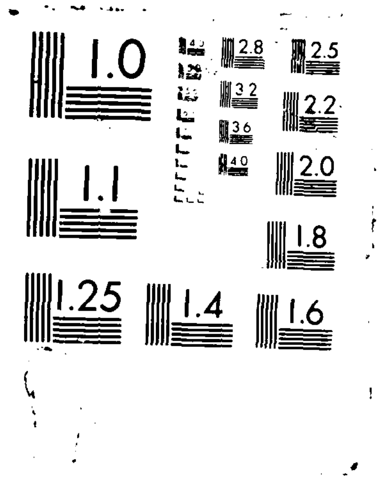
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FOREIGN TECHNOLOGY DIVISION

STUDY OF LIGHTNING AND LIGHTNING PROTECTION

(Selected Pages)

by

I.S. Stekol'nikov

PARTIALLY EDITED MACHINE TRANSLATION

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TABLE OF CONTENTS

U. S. BOARD ON GEOGRAPHIC NAMES TRANSLITERATION SYSTEM

Block	Italic	Transliteration	Block	Italic	Transliteration
А а	*А а*	A, a	Р р	*Р р*	R, r
Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere. When written as ё in Russian, transliterate as yё or ё.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	$\sinh^{-1}$
cos	cos	ch	cosh	arc ch	$\cosh^{-1}$
tg	tan	th	tanh	arc th	$\tanh^{-1}$
ctg	cot	cth	coth	arc cth	$\coth^{-1}$
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

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STUDY OF LIGHTNING AND LIGHTNING PROTECTION.

I. S. Stekol'nikov.

Page 101.

7. Ball lightning.

Sometimes in the atmosphere, near the ground, are observed special form discharges, which are igneous bodies, which float in air and are known by the name of ball lightning.

Most frequently appearance of ball lightning is connected with thunderstorm, but are known exceptions from this rule.

Let us give interesting observation of ball lightning, made many years ago by eyewitness in Kharkov region.

In calm, windless evening seemingly azure glowworm or weakly blinking light far suddenly appears. Phenomenon moves slowly - from the river, from the lowland/depression, to the elevation; motion ever is accelerated and, finally, the speed of sphere, it seemed, became such as in usual lightning. By size it was like a large children's ball. Noted first as azure, this sphere gradually was transformed into golden and flew in into the estate/farmstead of one peasant. The discharge, which had a character of the explosion of projectile, here occurred. All this continued fourth or third of minute.

With inspection of victim of estate/farmstead it was explained that lightning pleased into duct, even hot after furnace of Russian

furnace, it split it, did not break up, and its facade it riddled by shallow holes, seemingly variolar dimples, with value with large/coarse fraction.

Page 102.

People, which ate supper at the table, did not suffer - they were only dumbfounded, stunned. Shed in the court burned down from the scotomas. Neither thunderstorm nor storm nor wind gust after the described phenomenon happened; thus far nothing betokened a change in the calm, clear, warm weather.

But here is story of another eyewitness about ball lighting, generated by thunderstorm.

Matter occurred in Transcaucasia, on mountain road, going from Borzhomi to Akhalkalaki through crossing Mukhra-Tskharo (from transfer part of which in clear weather are simultaneously visible Caspian and Black Seas):

"After breaking out thunderstorm, hour through one-and-a-half, they entered into band of broken thunderstorm clouds, which crept into deep ravines, on edges of which way was twisted. Soon we left the sediment of clouds, and the ascending sun lit up us, and clouds were discharged increasingly below, wrapping ravines and gullies, which overgrew by coniferous forest. Around us forest vegetation already disappeared - only thickset prickly bushes and moss on the stones was encountered.

Recently sun was hidden behind remotest (fifth) circuit of mountains as overall attention it was drawn by fireball. By size/dimension and by form it greatly resembled the disk of moon at the moment of clear full moon, but it was surrounded by lilac-tinged-lilac glow, it inside seemed white-hot by the piece of iron, in which by zigzags became colored little sparks even more light than mass, and was heard light crackle. This ball as if wheeled along the edge of novice are somewhat above they were expensive the gorge (but not on his bottom). On the whole, the earth/ground it did not touch, but it accurately carried down by the air flow, moreover it ever more and more was separated/liberated from the earth/ground, and it seemed, as if it very rapidly rotates. It was given a ride from us in 10-12 meters. Sphere wheeled (or it swam) sufficiently slowly and crossed way (at the height/altitude less than the meter). then again it was deepened in the gorge and was hidden in the clouds thickened in it, sufficiently for long x-raying nevertheless in their misty thickness".

Many cases, when lightning discharge directly preceded appearance of ball lightning are described. This is what wrote observer in Transbaykal:

"Summer... Sufficiently clear weather; ran across cloudlet, slight rain, light breeze.

Page 103.

Lightning fell in rod apparatus, damaged it, after penetrating there, probably, on the lead/duct. From the rod apparatus it floated by air. Size/dimension approximately with the large children's ball, but changed form from the spherical to the oval. It slowly sailed through the open door into the adjacent telegraph room. Room small, windows were closed; lightning turned back into rod, then through the open door into the passenger hall of the III class and further through the open door into the luggage, finally, it left on the station pad. Nothing here it injured. Where it disappeared, it is unknown. The color of ball lightning was reddish-yellow".

On several interesting cases of ball lightning in Moscow and Moscow region in 1952-1954 eyewitnesses of these phenomena reported energy institute of Academy of Sciences of the USSR.

During August 1951 in the environs of Moscow it carried past hurricane of unusual force. According to the character of processes and damage, caused by hurricane, it relates to the discharge of the tornado (details of the development of this rare for middle latitudes phenomenon of nature described G. A. Remizov). Toward the evening at the horizon/level was formed the extremely developed of ominous form the thunderclouds of black-red color, threaded by bright lightning. Eyewitnesses noted that soon from the cloud to the earth/ground began to be discharged the vortex/eddy columns, which remind of giant sizes/dimensions elephantine trunks. It became dark, went cloudburst with the hail with value with the pigeon egg (separate hailstones

exceeded goose egg). Lightning glittered incessantly. Together with the set of linear, was noticed not less than five of spherical this quantity of ball lightning, observed during one thunderstorm, phenomenon very rare.

One of ball lightning penetrated in duct of house and here it was discharged. As a result of the subsequent explosion the duct was destroyed, and of the chimney of furnace several bricks, which fell to the floor in the room, were dislodged/chased.

Another ball lightning appeared before window of house, in which were dislodged/chased lower glass. It penetrated in the room; however, not through the lower part of the frame, but through the upper with the whole glass, in which melted the opening/aperture with a diameter of about one centimeter.

Page 104.

Ball lightning took the form of the incandescent sphere with value with fist.

Not long before appearance of ball lightning wind dislodged/chased glass and in opposite windows, threw open to door in rooms, so that through path through internal part of house was formed. Lightning crossed along the diagonal room, publishing weak crack and dispersing the fine/small, rapidly extinguished sparks, traversed the adjacent room, and then, without having caused harm, from the house

and, apparently, it was decomposed in the court.

Since ball lightning, appearing suddenly, exists from small fraction of a second to several minutes, and most frequently from 3 to 5 s., - to photograph it is very difficult.

Fig. 39. Ball lightning, which had diameter 8-12 m, and its accompanying three forked lightning (according to Jensen).

Page 105.

The facsimiles of ball lightning it is very small. Little we know also about their physical properties - about the temperature, internal structure, about the spectral composition of the emitted light/world, etc. An example of one of the rare photographs of ball lightning is given in Fig. 39. Three additional linear lightning discharges are here, besides ball lightning, taken/removed.

Usually ball lightning has form of watermelon or bulb. Ball lightning most frequently appears at the end of the thunderstorm in the form of the red glowing spheres by diameter from 10 to 20 cm. Rarely it has large sizes/dimensions. For example, lightning was

photographed with diameter approximately 10 m. Many cases, when ball lightning had complex form and different coloration, are described. So not long ago not far from Moscow, in Tomilino, was observed ball lightning with diameter of 16-17 cm with the unusually bright middle, which seemed igneous and it was surrounded by bright lilac-tinged light.

Lightning, noted in Gorlovka, was igneous ball with value with fist, irregular shape, red color with greyish-bluish hue.

Usually ball lightning publishes sibilant, buzzing or hissing sound.

It can disappear into some cases quietly, in others - with weak crack or even deafening explosion. Disappearing, it frequently leaves the sharply reeking mist. Near or closed indoors ball lightning moves with the speed of the running person - approximately 2 m per second. It can for a certain period of time remain in the rest, and this "deposited" sphere hisses and discards sparks until it disappears. It sometimes seems that ball lightning gonitis the wind, but usually its motion on the wind does not depend.

Ball lightning penetrate locations through open windows or doors, and sometimes even through small slots. Ducts present a good path for them; therefore ball lightning frequently appear from the furnaces in the kitchens. After being circled on the room, ball lightning departs

frequently along that path itself, along which it entered.

Sometimes lightning of two or three times is risen and is omitted to height/altitude from several centimeters to several meters.

Page 106.

Simultaneously with these uplifts and by descents the fireball is sometimes moved also in the horizontal direction. Then it seems that ball lightning jumps.

Frequently ball lightning "deposits" on conductors, preferring their highest points, or they wheel along conductors, for example, along drain pipes. Moving throughout the bodies of people, sometimes under the clothing, ball lightning cause strong burns and even death. Are described many cases of the lethal injury of people and animals by ball lightning. Ball lightning can cause extensive destruction to buildings.

Many researcher-theorists and experimenters persistently studied ball lightning; however, until now, could not be explained all its various manifestations. In this region an even more extensive scientific work remains.

Ball lightning many times attempted to obtain artificially in laboratories. In 1900 Russian physicist professor N. A. Gezekhus created electrical discharges on the surface of water. In this case

very beautiful light phenomena in the form of the oscillating flame or extremely movable balls/spheres appeared.

Are known other experiments, in course of which were obtained phenomena of electrical discharge, similar, but only on external form, small ball lightning.

Tens of hypotheses were devised for explaining mysterious behavior of ball lightning.

However, since ball lightning in real form reproduced thus far could not be, it is not possible to create their any reliable theory.

There was attempt to apply to ball lightning model of soap bubble, considering that role of soap solution here perform condensation products of reactive gases (ozone, oxides of nitrogen, etc.), which appear during discharge of lightning. However, the lot of the soap bubble understood this hypothesis.

It is known that electrical spark is capable of producing different chemical reactions, which lead to formation of such active materials as ozone or monatomic nitrogen, which in excited state for long glows. On this basis different assumptions about the fact that ball lightning is the mixture of reactive gases with air were constructed.

Page 107.

According to series/row of assumptions, ball lightning is formed by vortex/eddy of chemically active gases, agitated with solid dust particles and smokes. Due to the energy, given up by dust particles to reactive gases, occurs their strong heating and appears the brightness of spherical cluster. If for any reasons the rapid decomposition of vortex/eddy occurs, ball lightning disappears soundlessly, also, without the consequences. Otherwise the explosion, which is large valid, can occur.

The fact that, for example, decomposition of ozone to oxygen occurs explosion-like, with liberation of very large quantity of heat, is certain confirmation of such assumptions.

According to one of theories, ball lightning is phenomenon of decomposition of water vapors, which are contained in air, under action of high temperature, caused by current of forked lightning. In this case they assume that under the action of the high temperature in the channel of the forked lightning, which exceeds 6000°, the decomposition of the fractions/particles of water to the molecules of hydrogen and oxygen occurs. Possibly also the conversion of molecular hydrogen into the atomic. After the cessation/discontinuation of the current of lightning cooling channel begins.

It is assumed that hydrogen-oxygen mixture of gases upon reaching/achievement of corresponding temperature can with explosion

be converted into water. The described phenomena are accepted for the basis of the process of forming ball lightning. It is considered further that the heated hydrogen-oxygen gas, which is found in cold air, obeys the law of the surface tension, which attempt to reduce the surface of gas volume to minimal sizes, i.e., to the spheroidal state. The shape of surface of hydrogen-oxygen mixture will depend on the state of surrounding air.

Properties of hydrogen-oxygen mixture explain some of known properties of ball lightning.

So, for example, the fact that ball lightning, which possesses in its volume extremely high temperature, as is known, ignites combustible objects, is explained, on the basis of this theory, by fact that radiation of pure/clean mass of gas is usually small, especially then, when it is reflected in opposite direction by smooth bounding surface; in this case between ball lightning and any body, which it approaches, intermediate layer of vapor, which blocks heat transfer, is formed.

Page 108.

This phenomenon is well known from the observations of the drop of the water, which fell to the incandescent metallic surface. Forming in this case water ball/sphere remains for a while on the metal, without evaporating, precisely, due to the "spheroidal state".

Ability of ball lightning to float in air and to accomplish upsurges is explained by the fact that hydrogen-oxygen mixture has specific volume to 50% larger than water vapors at the same temperature. The high temperature of mixture contributes to the same.

Frequently observing metallic flare of ball lightning is explained by sharply outlined surface, which reflects well light. The described theory is based on assumption about the existence of the forces of surface tension, which appear between two masses of gas, temperature and composition of which is very different.

This assumption does not have experimental substantiation and thus is only hypothesis.

On investigations of P. N. Chirvinskiy, explode can not only detonating gas, which appears during decomposition by lightning of water into oxygen and hydrogen, but also nitrogen oxides forming during electrical discharges.

From many attempts at experimental reproduction of ball lightning it is possible to note experiments of Knauer, during which are recently obtained phenomena, in many their features similar to ball lightning.

Experiments were conducted in glass tubes with length of from 50 cm to 2 m with inside diameter of 6-8 cm (in certain cases diameter of tube reached to 23 cm).

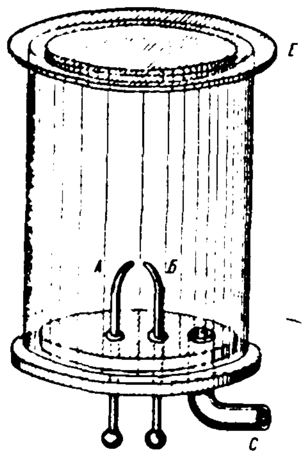

Fig. 40. Installation for obtaining artificial ball lightning.

Page 109.

As electrodes served two slightly bent at ends/leads iron edges A, B, with distance between points from 5 to 10 mm (Fig. 40). The introductions/inputs of electrodes were sealed in into the bottom of tube and consolidated. Branch C for connection of pump here was located. On top the tube was closed with the aid of Pertinax glass or metallic cover/cap. Small inductor served as the voltage source.

In container certain quantity of combustible gases was introduced.

Upon short-term switching on of electrode voltage between them jump spark, which leaves after itself luminous cloud.

Detailed study of nature of this cloud showed that it is result

of burnout of hydrogen in air.

It has already long ago been known that with small quantities of hydrogen in air its burnout in the form of luminous cloud occurs.

Nec ssary concentration of gas or vapors in air is different for different substances. Thus, for propane light clouds are obtained well with 1.24% of its content in air; for hydrogen these luminous clouds are obtained with 3.8-9%.

In the case of very small additions of gas, following sparkover immediately appears sufficiently movable (with length to 1.5 cm) flame usually of matte-azure color; with increase in gas concentration flame reaches height/altitude of 15 cm and can be observed very long time. With the even higher concentrations sometimes are observed the breakaways of luminous cloud, which independently flies about 20 cm.

Described phenomenon was observed at different air pressure from 40 mm Hg column to atmospheric pressure. Its percentage of gas additive corresponds to each pressure. The appearance of luminous cloud very little depends on pressure. The majority of experiments was conducted at room temperature. The moisture content in air of container does not affect phenomenon. Magnetic and electric fields also do not have on it an effect.

Page 110.

Appearance of luminous cloud is changed during its existence. Appearing about discharger in the form of small ball/sphere, cloud for several seconds, during which it is risen to the head of container, it is converted into the large body. In other cases the luminous cloud on its path slowly decreases, and sometimes large cloud decomposes into the set of small, which subsequently can partially again reunite. Luminous clouds are of all possible colors - blue, green, violet, etc. Color depends both on the burning gas and on the admixtures/impurities of air. Luminous intensity is very different for different gases. With hydrogen the very weak blue brightness, noticeable only in the darkness, is observed, with benzene vapor or propane brightness are well visible in the completely light location. The speed of the displacement/movement of light cloud lies/rests in limits of 1/3-10 m per second and is changed against the time of its displacement/movement. Being moved, cloud produces no noise. The disappearance of cloud occurs either during uplift or with the contact with upper cover. In the latter case the crack sometimes appears. During the opening of container sharp/acute odor from the combustion products is perceived. As the visible remainder/residue of luminous cloud the fog is obtained. Light cloud in certain cases is capable of passing through 7- millimeter opening/aperture to metallic diaphragm.

Theory of luminous cloud is not yet developed. Its described properties have much in common with observed natural ball lightning. Here are involved such properties, as appearance, color, luminous intensity, speed of the motions, which accompany its sounds and

noises, remainder/residue, after disappearance, clouds in the form of greyish-brown fog, neutral relation to the metallic bodies and the ability to penetrate through the opening/aperture in the metallic bodies. The series/row of other properties of artificial and natural ball lightning requires supplementary study and comparison.

From experiments described above it follows that for forming ball lightning it is necessary that in nature, in specific airspace, there would be small concentration of any combustible gas. Since the combustible gases are found in air in the required concentration extremely rarely and since for their ignition the electrical discharge (lightning or spark in electrical plant) must near them occur, the simultaneous coincidence of all these factors is little probable, which is located in accordance with the rare appearance of ball lightning.

Page 111.

Described experiments show that luminous cloud, which reminds ball lightning, is not electrical phenomenon. Electrical spark here served only for the ignition of the gases, available in air.

Information, which are obtained by science about ball lightning, thus far it is still very modest, and necessary great work for complete explanation of this variable and capricious satellite of violent manifestations of atmospheric electricity.

In this question essential aid they can show/render detailed descriptions of ball lightning, made by random eyewitnesses.

8. Black lightning.

In some photographs, which are encountered in the literature, lightning of black color is visible. This peculiar phenomenon was until recently surrounded by complete mystery. In A. I. Kuprin's story "Black lightning" by words Turchenko is described the death of man swamp/marsh on stormy night. "This was one of the terrible thunderstorms, which burst sometimes above the large lowlands. Sky did not flash from the lightning, but accurately all shone by their timid azure, blue and vividly white flare. And thunder did not grow silent not on instant... And thus I saw black lightning. I saw, how from the lightning sky rocked in the east, without having been extinguished, but always first being swept, then being compressed, and suddenly before this varying by fires/lights azure sky I with the unusual clarity saw instantaneous and glaring black lightning..." and further: "O, that this was after the terrible night! These black lightning aimed at me the inexplicable animal fear".

On black lightning mentions in its "song about stormy petrel" of A. M. Gor'kiy:

... Between clouds and sea.
Proudly glides stormy petrel.
Black lightning similar...

Page 112.

However, in actuality lightning, colored black, does not exist. Their appearance on the photographic plate is explained by the discontinuity of the action of light/world. If we photographic emulsion illuminate first by short flash/burst of light of very high intensity, and then - by the light of moderate force, then negative image can become positive.

During strong thunderstorm, when different intensity of lightning they follow one after another with short time intervals, can be created exactly such conditions for inversion of image. This means that, instead of, against the dark/nonluminous background of photographic film the light band of lightning would appearing, is obtained reverse/inverse picture - black lightning against the light background.

It is interesting that also in Kuprin's story it is said about the fact that black lightning could be result of error of view, tired by continuous game of lightning on entire sky...

Page 158-159.

Table of contents.

DISTRIBUTION LIST

DISTRIBUTION DIRECT TO RECIPIENT

ORGANIZATION	MICROFICHE
A205 DMAHTC	1
A210 DMAAC	1
B344 DIA/RTS-2C	9
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C509 BALLISTIC RES LAB	1
C510 R&T LABS/AVRADCOM	1
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C535 AVRADCOM/TSARCOM	1
C539 TRASANA	1
C591 FSTC	4
C619 MIA REDSTONE	1
D008 NISC	1
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E408 AFWL	1
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E429 SD/IND	1
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